Marketing Research Report No. 923

STORAGE AND SHELF LIFE OF PACKAGED KALE

Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTU

PREFACE

We appreciate the cooperation of Homer F. Weston and his staff at Safeway Stores, Inc., Washington, D.C., who packaged fresh kale to order as needed for the experiments.

R. E. Hardenburg assisted in planning the experiments, R. E. Anderson advised on respiration measurements, G. A. Brown assisted with respiration titrations, and H. S. Dory assisted with the kale inspections. They are all employees or former employees of the Market Quality Research Division of the Agricultural Research Service, Beltsville, Md.

This marketing research is part of a continuing program to reduce marketing losses and to extend the marketing season of agricultural products. The specific study of packaged fresh kale described in this report was undertaken to find improved methods for the handling, storage, and packaging of this highly nutritious food crop.

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Washington, D.C. Issued October 1971

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 Price 20 cents

STORAGE AND SHELF LIFE OF PACKAGED KALE

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BACKGROUND

Raw, trimmed kale has twice the food energy of, and generally higher vitamin and mineral content than, most other leafy green vegetables (greens) (*14*).[1] When kale is properly handled and refrigerated, its food value remains high (*4, 5*), and much of this food value is retained in the cooked product (*14*).

Kale, which comprises about 5 percent of the greens marketed in the United States, is grown to some extent in most States and is available at the major market centers every month of the year. About 60 percent of the kale crop is grown for use in the cold months, December through March; 30 percent is grown for use in the moderate spring and fall months; and 10 percent is grown for use in the warm months of June, July, and August. Figures for commercial kale plantings included in the 1964 Census of Agriculture (*7, p. 442*) showed a total of 3,008 acres divided among more than 30 States. Leading kale-producing States and acreage included Virginia, 1,111; Maryland, 417; Texas, 275; Tennessee, 216; Arkansas, 202; Georgia, 199; Ohio, 124; and New Jersey, 93. North Carolina, South Carolina, Kentucky, and Florida each had about 50 acres in kale production.

At harvest, kale leaves are either stripped from the plant and crated in the field, or clipped plants are brought to a packing shed for bunching or stripping and crating. Commonly used shipping containers are the round-bottom wood bushel basket and the 1- or 1⅑-bushel wirebound wood crate. In moderate- to long-distance shipments, loads are refrigerated by both package and top icing (*1, 10, 13*).

In commercial operations at marketing centers, kale from crates and baskets is either washed, sorted, and packaged in 10-ounce perforated cellophane bags, or it is placed in wood containers and held overnight at about 40° F. before it is packaged. After the kale is packaged, it is packed in master cartons (12 bags per carton). The master cartons of packaged kale are held 2 days or less at 40° until delivered to stores. On the average, 1 bushel of kale yields twenty-four 10-ounce packages. According to one report, the cost of washed, trimmed, and packaged kale is about twice that of bulk kale (*11*). The U.S. Department of Agriculture estimated in 1964 that 85 percent of the kale marketed in the continental United States is packaged as consumer units in 10-ounce film bags before it reaches the retail stores.

Vitamin C and provitamin A (carotene) are rapidly lost from kale wilted by being held in a low humidity and are lost much more rapidly from kale that is also held at a high temperature. During a 4-day holding period, vitamin C loss from kale held at 32° F. is about 2 percent at high humidity and 15 percent at low humidity; at 70°, vitamin C loss is about 78 percent at high humidity and 93 percent at low humidity (*4, 5*). Kale processed by dehydration retains about half of its original vitamin content after dehydration and 5½ months' storage in air at 75°, and it retains slightly more than half of its vitamin content when stored at 32° in 100-percent carbon dioxide (*3*).

Previously recommended storage conditions for freshly harvested kale are 32° F. and 90- to 95-percent relative humidity, with an approximate storage time of 10 to 14 days (*9*). The highest freezing point for kale leaves is 31.1° (*15*). Al-

[1] Italic numbers in parentheses refer to literature cited, page 19.

though packaged and bulk kale is displayed in retail stores at 40° to 50°, a lower temperature (near 32°) is preferable. Recommended storage temperature range for reserve kale supplies held for marketing is 32° to 40°, with 90- to 95-percent relative humidity (*8*).

Bacterial soft rot (*Erwinia carotovora*) is cited as the most important postharvest disease of kale. Diseases such as watery soft rot (*Sclerotinia sclerotiorum*) that affect cabbage and related crops also occur in kale (*12*).

TEST OBJECTIVES, MATERIALS, AND PROCEDURES

This report describes a study conducted from January through July 1968 to find ways of preventing deterioration of packaged fresh kale, and of prolonging its storage and shelf life. Research for the study was directed toward a series of tests in which sorted and unsorted fresh whole kale leaves and fresh packaged whole kale leaves were given various prestorage treatments and then subjected to different storage and holding environments for various periods of time. Throughout the tests, emphasis was placed on finding better storage and holding methods for washed and for unwashed fresh kale stored in wood shipping and storage containers, or packaged as consumer units in 10-ounce cellophane bags.

Before the major storage and shelf-life tests were begun, preliminary tests and observations were made. Research was also undertaken to determine the respiration and heat evolution rates of whole kale leaves and kale leaves cut into strips. More fresh kale was then obtained from a commercial source and treated in the prestorage, storage, and holding tests described in detail in the section of this report titled "Storage and Shelf-life Tests."

Approximately 80 bushels of curly and smooth kale were used in the tests. About 2 bushels were used for preliminary tests and observations and for the respiration studies, and 78 bushels were used for the handling, storage, and shelf-life tests. All of the kale used was field grown in Texas or in Virginia and was placed in tests soon after it arrived at a commercial packaging plant in the Washington, D.C., marketing area.

The Texas-grown kale was packed in two types of containers: 14 field-packed round-bottom bushel baskets; and 100 Saran-coated cellophane bags, each with eight ¼-inch perforations, and each with a 10-ounce capacity. The Virginia-grown kale was packed in three different containers: 44 field-packed wirebound crates, each with a 1-bushel capacity; eight field-packed wirebound crates, each with a 1¼-bushel capacity; and 144 cellophane bags identical with those used for the Texas-grown kale.

For test purposes, bulk kale from selected field-packed wood shipping containers [2] was given one of several different treatments before it was transferred from the commercial packaging plant to nearby Government facilities for the storage and shelf-life tests. Each container was either lined or overwrapped with polyethylene film. Some of the field-packed kale was iced and overwrapped only before it was transferred from the commercial packing plant to the laboratory. Kale from other containers, however, was commercially washed, inspected, and sorted before being recrated in lined containers and iced.

The kale that was packaged by the commercial plant was taken from newly arrived field-packed shipping containers. Most of this kale was commercially washed, sorted, and spin dried before it was packed into the cellophane bags. Some of the kale, however, was treated separately so that the effects of storage and holding on washed and unwashed packaged kale leaves could be evaluated. Part was placed on a dry belt for sorting before it was packaged as consumer units of unwashed kale. The rest was placed on a belt feeding into the vegetable washer, sorted, and packaged as consumer units of washed kale. All of the cellophane bags used for packaging were heat sealed after they were filled.

After these prestorage treatments, the test kale was transported by truck to USDA research facilities at Beltsville, Md. Approximately one-half hour's transport time was required. Both the field-grade bulk kale and the washed bulk kale were

[2] For the purposes of this report, the term "wood shipping (and storage) container(s)" includes both the bushel baskets and the 1- and 1¼-bushel wirebound crates.

iced, transported, and experimentally stored in shipping containers (fig. 1). The packaged kale was packed for transport and storage into corrugated master cartons with full telescope lids (fig. 2). Each master carton held two six-package layers that were separated by a paper packet of snow ice.

All prestorage, storage, and holding examinations and tests described in this report were made in the Beltsville laboratory. When the containers and cartons arrived at the laboratory, some of both the bulk kale and the consumer-packaged kale was removed for prestorage examinations and the rest of the kale was immediately placed in refrigerated storage. During the storage tests, kale was periodically removed from the wood shipping containers and the cartons for examination. In these examinations, the kale removed from the wood shipping containers was sorted, and commercially objectionable vegetable and foreign matter was removed. The remaining high-quality kale was then handpacked in the laboratory into cellophane bags identical with those used for the packaged kale obtained from the commercial packaging plant (Saran-coated cellophane bags with eight ¼-inch

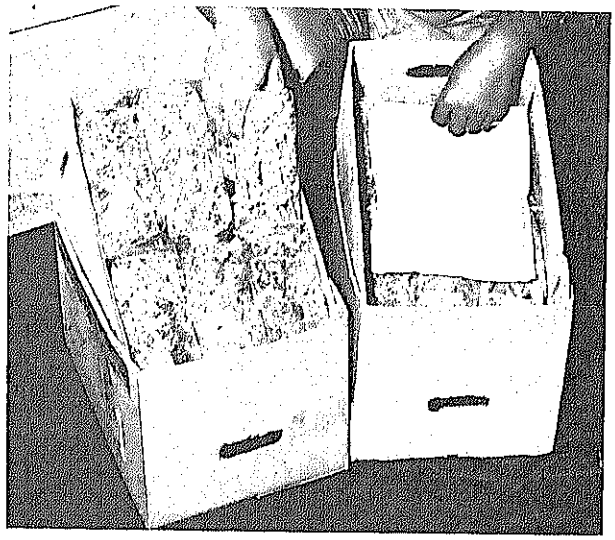

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FIGURE 2.—Corrugated master cartons used to ship and store fresh kale commercially packaged in 10-ounce perforated cellophane bags. *Left*, Each carton holds 12 bags arranged in two six-bag layers. *Right*, Top layer of bags has been removed to show waterproof paper packet of snow ice placed between the two layers. Cartons can be closed with the complete telescope covers and can serve as storage containers at destination.

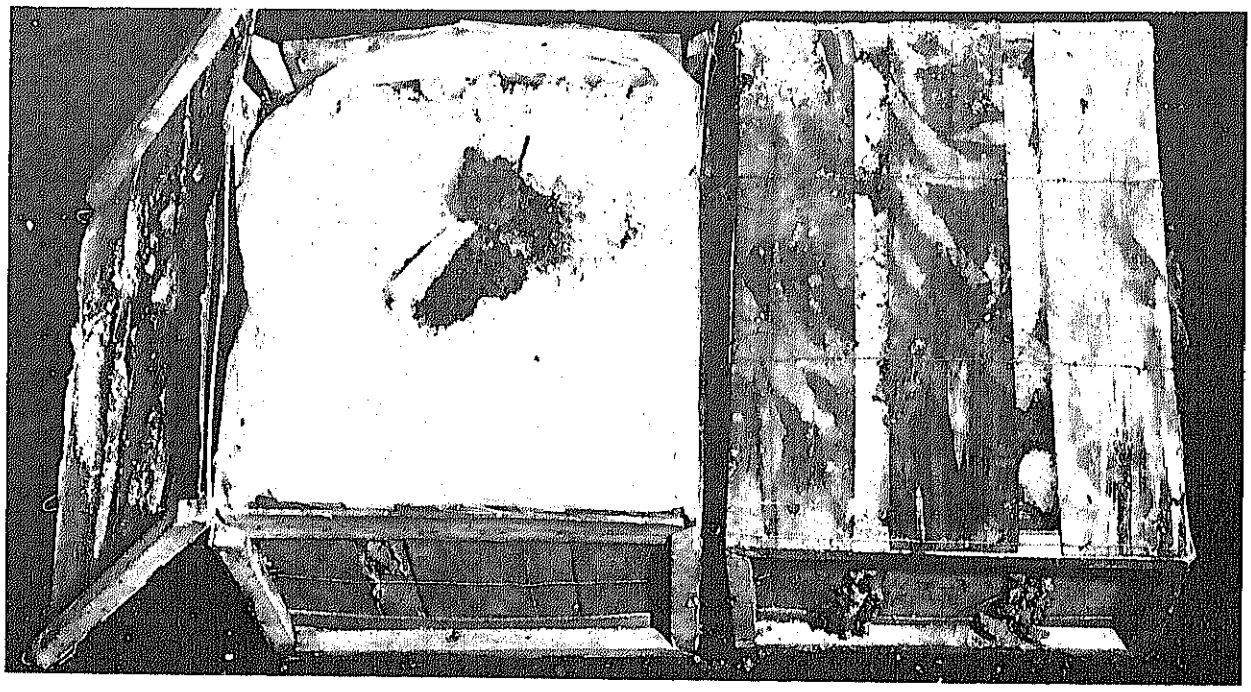

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FIGURE 1.—For storage-life tests, fresh kale was covered with snow ice and stored for 6 weeks at 32° F. in lined or wrapped 1-bushel wirebound wood shipping crates. *Left*, Container for washed and sorted kale was lined with 1.5-mil perforated polyethylene. *Right*, Container for unwashed field-packed kale was not lined but was overwrapped with polyethylene film during storage.

perforations). Both the packaged kale provided by the commercial packaging plant and the packaged kale prepared in the laboratory were held for 1 to 4 days before or after storage in the shelf-life tests. During these tests, packages were periodically removed for examination.

To distinguish between the consumer units packaged by the commercial plant and those prepared in the Beltsville laboratory, the term "commercially packaged" is used in this report for the units obtained from the plant and the term "experimentally packaged" is used for the units prepared in the laboratory. The term "consumer unit(s)" is used generally for kale commercially or experimentally packaged in 10-ounce film bags.

The storage tests were conducted to determine the prevalence of decay and yellowing in fresh washed and unwashed kale stored under various conditions for different periods of time, and to obtain storage histories for kale used in the shelf-life tests. The holding, or shelf-life, tests were designed to determine the amount of weight loss, decay, and yellowing occurring in packaged fresh washed and unwashed kale held under simulated retail shelf conditions, and to rate the appearance and salability of this kale before, during, and after experimental holding. Percentages for weight loss, decay, and yellowing were based on the weight lost or the weight of defective leaves, and the total initial weight of kale placed in the consumer-unit bag.

PRELIMINARY TESTS AND OBSERVATIONS

Before the main tests were begun for this study, preliminary tests on holding packages of kale were made and evaluated. In one exploratory test, fresh kale grown in Texas was shipped to Washington, D.C., in containers under refrigeration with container and top ice. This kale was commercially packaged as consumer units in 10-ounce perforated (eight ¼-inch holes) Saran-coated cellophane bags soon after arrival. The packaged kale was then transferred to the nearby USDA research facilities at Beltsville, Md., where it was held for 4 days at the following temperatures:

(a) 70° F. with 50- to 75-percent relative humidity.

(b) 60° F. with 75- to 85-percent relative humidity.

(c) 50° F. with 75- to 85-percent relative humidity.

(d) 40° F. with 85- to 95-percent relative humidity.

(e) 32° F. with 85- to 95-percent relative humidity.

The packaged kale retained its "excellent" appearance when held 1 day at 70°, 60°, or 50° F., and for at least 4 days at 40° or 32° (table 1). The appearance was rated "good" when the kale was held for 2 days at 60° or 50°, but its appearance deteriorated to "poor" when it was held for 3 days at 70° or 60°, or for 4 days at 50°. Commercially objectionable yellowing affected 63, 56, and 22 percent of the leaves in packages held for 4 days at 70°, 60°, and 50°, respectively (figs. 3 and 4). However, kale held at 32° or 40° was still free of yellowing after 4 days. Even at the higher temperatures, some leaves in each package retained good green color after 4 days.

In another test, severe yellowing and some bacterial soft rot developed in kale held for 3 days at 70° F., and by 5 days, some leaf veins were black. Kale stored for 3 weeks at 32°, however, remained fresh and green. Longer kale storage tests are described in this report in the section titled "Storage and Shelf-Life Tests."

The new, dry, Saran-coated cellophane bags felt stiff and crackeled when handled. Before they were filled with kale, the new, dry bags weighed about 6 grams each. A short time after each bag was filled, its film became soft and pliable. The bags were then found to weigh about 12 grams each; this weight increase indicates that water was absorbed by the film. Appearance of the film bags and visibility through the film was excellent in preliminary observation and throughout later tests.

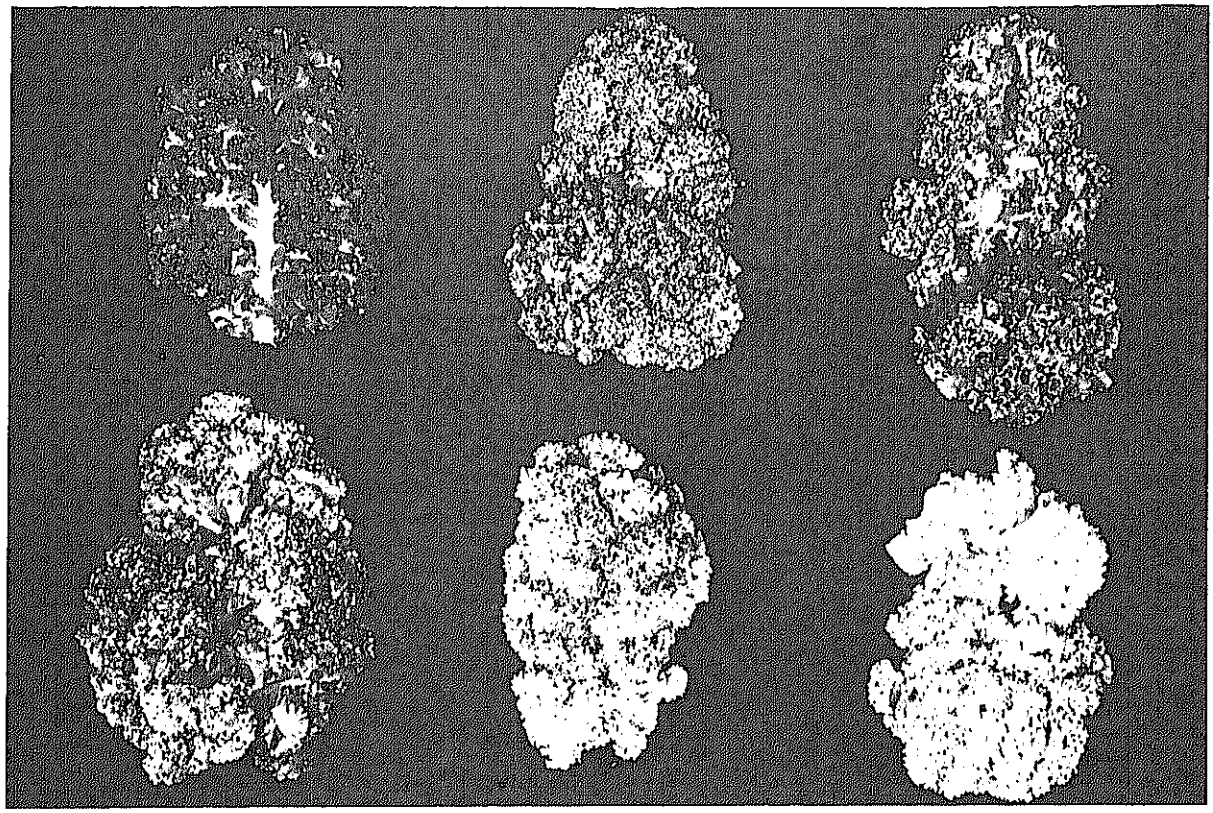

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FIGURE 3.—Kale leaves illustrate yellowing standards. Leaves in top row (*left to right*) were rated "green" (no yellowing), "trace," and "slight." Leaves in bottom row (*left to right*) were rated "moderate," "severe," and "extremely severe." Leaves in bottom row only have commercially objectionable yellowing.

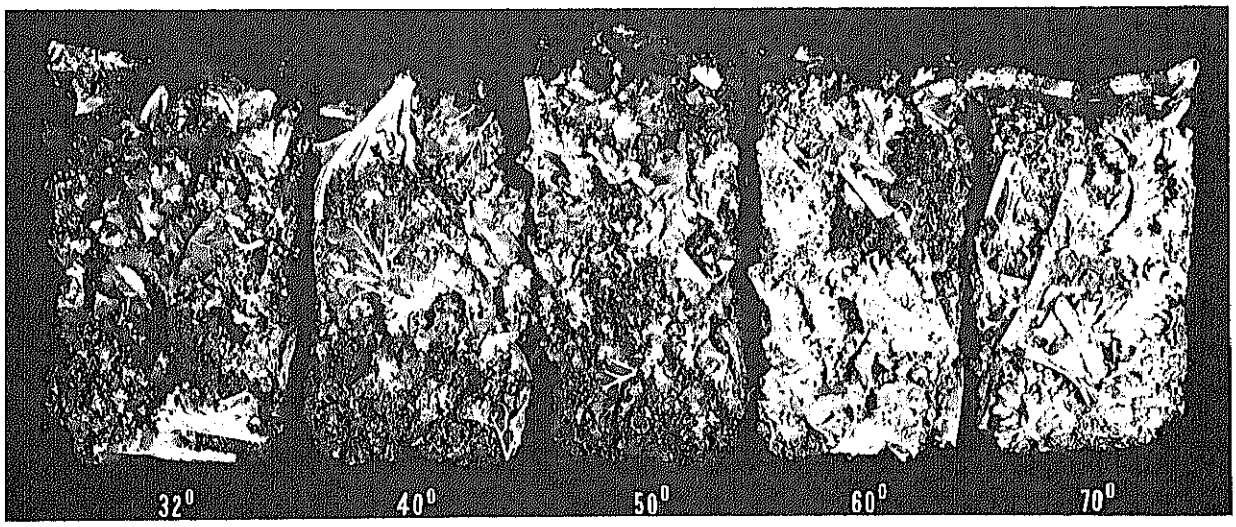

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FIGURE 4.—Kale packaged in 10-ounce perforated Saran-coated cellophane bags (front sides cut away) after 4 days' holding at indicated temperatures. *Left to right,* Leaves of kale held at 32° and 40° F. show no commercially objectionable yellowing, but 22 percent of the leaves held at 50° have moderate yellowing, 56 percent of the leaves held at 60° have severe yellowing, and 63 percent of the leaves held at 70° have extremely severe yellowing.

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TABLE 1.—*Condition of fresh kale packaged as consumer units in film bags* [1] *and held for 1 to 4 days at 32° to 70° F.* [2]

Holding temperature and time [3]	Weight loss	Yellowing [4]	Appearance	Salability
70°:	*Percent*	*Rating*	*Rating*	*Rating*
1 day	2.9	Trace [5]	Excellent	Salable.
2 days	8.0	Slight	Fair	Do.
3 days	12.1	Moderate	Poor	Not salable.
4 days	15.0	Severe	Very poor	Do.
60°:				
1 day	1.1	Trace [5]	Excellent	Salable.
2 days	2.0	do [5]	Good	Do.
3 days	3.2	Moderate	Poor	Not salable.
4 days	4.3	Severe	do	Do.
50°:				
1 day	.6	Trace [5]	Excellent	Salable.
2 days	1.1	do [5]	Good	Do.
3 days	2.0	Slight	Fair	Barely salable.
4 days	2.5	Severe	Poor	Not salable.
40°:				
1 day	.3	Trace [5]	Excellent	Salable.
2 days	.9	do [5]	do	Do.
3 days	1.2	do [5]	do	Do.
4 days	1.5	do [5]	do	Do.
32°:				
1 day	.3	None	do	Do.
2 days	.9	do	do	Do.
3 days	1.2	do	do	Do.
4 days	1.9	do	do	Do.

[1] Test kale was in 10-ounce Saran-coated cellophane bags, each perforated with 8 ¼-inch holes.

[2] Relative humidities were: 50 to 75 percent at 70° F., 75 to 85 percent at 60° and 50°, and 85 to 95 percent at 40° and 32°.

[3] When placed in holding rooms, test kale was free of yellowing, "excellent" in appearance, and salable.

[4] Yellowing ratings of moderate, severe, and extremely severe only were commercially objectionable (figs. 3 and 4).

[5] Trace of yellowing found in 1 leaf only.

RESPIRATION AND HEAT EVOLUTION RATES

Before the storage and shelf-like tests were begun, research was conducted to obtain respiration and heat evolution rates for whole kale leaves and for kale leaves cut into strips. Using adaptations of methods of Brown and Escombe (*2*), and of Hart (*6*), respiration rates were estimated as milligrams (mg.) of carbon dioxide (CO_2) produced per kilogram (kg.) of fresh kale per hour (mg. CO_2/kg./hr.) at each of several holding temperatures (table 2). Heat evolved was calculated by

TABLE 2.—*Rates of respiration and heat evolution for fresh kale held at 5 temperatures* [1]

Holding temperature (° F.) for kale [2]	Whole leaves from bushel crates [3]		Whole leaves from cellophane bags [3]		Leaves cut into strips (from bushel crates) [3]	
	Respiration rate range [4]	Heat evolution rate range [4]	Respiration rate range [4]	Heat evolution rate range [4]	Respiration rate range [4]	Heat evolution rate range [4]
	Mg. CO_2/kg./hr.	*1,000 B.t.u./ton/24 hr.*	*Mg. CO_2/kg./hr.*	*1,000 B.t.u./ton/24 hr.*	*Mg. CO_2/kg./hr.*	*1,000 B.t.u./ton/24 hr.*
70°	186–265	40. 9–58. 3	174–273	38. 3–60. 1	230–314	50. 6–69. 1
60°	120–155	26. 4–34. 1	92–163	20. 2–35. 9	132–215	29. 0–47. 3
50°	72–84	15. 8–18. 5	65–113	14. 3–24. 9	79–113	17. 4–24. 9
40°	34–47	7. 5–10. 3	32–48	7. 0–10. 6	40–55	8. 8–12. 1
32°	16–27	3. 5–5. 9	21–27	4. 6–5. 9	21–31	4. 6–6. 8

[1] At indicated temperatures, respiration rates, expressed as milligrams of carbon dioxide produced by 1 kg., of kale per hour (mg. CO_2/kg./hr.), were multiplied by the factor 220 to convert rates to British thermal units per ton of kale per 24 hours (B.t.u./ton/24 hr.). (*See* Lutz and Hardenburg (*9*).)

[2] When tested at the 1-percent level of statistical significance, respiration and heat evolution rates for kale held at each of the 5 temperatures were found to be significantly different from rates at the other 4 temperatures.

[3] Respiration and heat evolution rates for whole kale leaves from field-packed bushel crates were not statistically significantly different from rates for whole kale leaves from commercially packaged 10-ounce cellophane bags. However, rates for kale leaves cut into strips were statistically significantly higher (1-percent level) than rates for both groups of whole leaves.

[4] Ranges are based on readings of 6 replicated tests.

multiplying the rate mg. CO_2/kg./hr. by the factor 220 to get British thermal units per ton of kale per 24 hours (B.t.u./ton/24 hr.). This conversion is explained by Lutz and Hardenburg (*9*), with other information on respiration.

Six replicates of about 105 grams each of fresh kale were placed in 1-gallon jars, each fitted with a capillary breather tube. Time was allowed for the kale to come to equilibrium with the holding temperature before carbon dioxide collection was started. The carbon dioxide produced during 1 day at temperatures of 70°, 60°, 50°, 40°, or 32° F. reacted with part of the 50 milliliters (ml.) of potassium hydroxide in a 250 ml. beaker to form potassium carbonates. When barium chloride was added to the solution, barium carbonate precipitated. The remaining unreacted potassium hydroxide was then titrated with hydrochloric acid to a phenolphthalein end point, and the barium carbonate was titrated to a methyl orange end point.

Whole kale leaves from the field-packed bushel containers and from the commercially packaged 10-ounce cellophane bags respired within slightly different ranges but at about the same average rate. Kale leaves taken from the bushel shipping containers and cut into strips respired at rates about 20 percent faster than rates for whole kale leaves taken from the same source. Respiration rates more than tripled for every 18° to 20° rise in temperature between 32° and 70° F. Thus, respiration rates at 70° were about 10 times as fast as rates at 32°.

STORAGE AND SHELF-LIFE TESTS

Kale Stored in Wood Shipping Containers

Prestorage Treatments

The bulk kale shipped from Texas and Virginia in wood shipping and storage containers received different handling and wrapping treatments after it arrived at the cooperating packaging plant in Washington, D.C. The 14 round-bottom bushel baskets of Texas-grown kale and the eight 1¼-bushel wirebound crates of Virginia-grown kale were each iced with one shovelful (10 pounds) of snow ice and each was then overwrapped with a

1.5-mil polyethylene bag perforated with 100 3/16-inch holes. The 1-bushel wirebound crates of Virginia-grown kale were given special treatment for comparative tests of washed and unwashed kale. Half (22) of the forty-four 1-bushel crates received one shovelful of snow ice each, and each crate was then individually overwrapped with perforated polyethylene film. The other 22 crates were each opened, and the fieldgrade kale they contained was commercially washed, inspected, sorted, and recrated into new 1-bushel crates, each of which was lined with a perforated polyethylene film bag. One shovelful of snow ice was put over the washed and sorted kale in each lined crate before the liner and lid were closed (fig. 1).

Prestorage and Storage Examinations

After the containers of iced kale arrived at the Beltsville laboratory, samples were removed for immediate examination and evaluation of the kale's prestorage condition. The rest of the kale was left in the wood shipping containers, which were placed in storage at temperatures of either 32° or 40° F. both at 85- to 95-percent relative humidity. Kale in the 1¼-bushel crates was held at 32° only.

At each weekly examination, 7.5 pounds of kale were removed from each of two representative storage containers from each of the separate prestorage-storage treatments.

The kale was inspected for decayed, yellowed, or coarse leaves and stalks, and for foreign matter such as weeds, dirt, and straw. Undesirably coarse kale consists of tough, weatherbeaten, or old leaves; excessively thick petioles (stalks); and central stalks with or without seed stems. Decay and yellowing percentages were based on weight of leaves affected with decay or with moderate, severe, and extremely severe yellowing, and total weight of the sample. (Yellowing standards for kale are shown in figure 3.) Yellowing percentages reported did not include trace and slight yellowing, which are not commercially objectionable. However, leaves with trace and slight yellowing as well as leaves with commercially objectionable yellowing were discarded after each sample was examined.

The high-quality kale that remained after this sorting process was then hand-packed as consumer units in the 10-ounce Saran-coated bags described earlier in this report. Some of these experimentally packaged consumer units of kale were examined immediately, and the rest were placed in a 70° F. holding room with 75-percent relative humidity for 1, 2, or 3 days of experimental holding.

In general, each of the 1-bushel shipping containers of kale weighed about 30 pounds, with the following weight distribution: Watersoaked container, 6 pounds; ice, slightly less than 10 pounds; and other contents (kale and foreign matter), slightly more than 15 pounds. The 1¼-bushel crates weighed about 40 pounds each. The contents of each container examined included an average 10 to 15 percent of coarse, unsalable kale stems and leaves and an average 1 percent of foreign matter. Thus, for field-packed kale, the average yield of high-quality salable kale suitable for packaging as consumer units was 12.5 to 13.5 pounds per bushel.

Storage Life of Unwashed Kale in Field-Packed Wood Shipping Containers

Results for this test are described below without the use of tables. Before being stored in the wood containers, none of the field-packed kale was yellowed, but up to 8.4 percent was decayed. During storage at 32° F., decay and yellowing developed erratically. For example, the kale in each of three wood containers averaged less than 5 percent decay during 4, 5, and 6 weeks of storage, whereas in kale in other wood containers, decay increased from 7.4 percent before storage to over 20, 25, and 35 percent during 4, 5, and 6 weeks of storage, respectively. During 7 weeks of storage at 32°, no yellowing was noted in the kale that decayed the most. However, in kale with low decay percentages, yellowing developed steadily, and an average of over 20 percent of the kale leaves were affected during 6 weeks of storage in wood containers. Decay probably masked leaf areas that might have yellowed had the kale been decay free.

Decay and yellowing developed at a more regular and much faster rate in kale stored at 40° F. than in kale stored at 32°, although some differences in levels of prevalence existed between the kale in individual containers. No increase in decay occurred during 1 week of storage at 40°. However, at the 2-, 3-, and 4-week examinations, decay levels in kale averaged 22, 48, and 80 percent, respec-

tively. During 3 weeks of storage in wood containers at 40°, over 55 percent of the kale yellowed. In most kale stored at 32° or 40°, decay and yellowing were found on separate leaves. Field-packed unwashed kale in wood shipping and storage containers stored well at 32° for 4 to 5 weeks (some stored well for 6 weeks) with an estimated 65- to 95-percent of the leaves remaining marketable. However, by the seventh week at 32°, kale from the field-packed wood shipping containers was 70- to 75-percent decayed.

The field-packed kale also stored well for a maximum of 2 weeks at 40° F.; 60 to 85 percent of the leaves remained marketable. But by 3 weeks at 40°, 75 to 100 percent of the leaves were decayed or yellowed, or both. Kale in containers in which some of the original snow ice remained until the time of examination stored better than kale in containers depleted of snow ice.

Storage Life of Washed and Unwashed Kale in Wood Shipping Containers

As explained under prestorage treatments, kale in half of the 1-bushel field-packed shipping containers used for the comparative test of washed and unwashed kale leaves (table 3) was snow iced immediately on arrival at the commercial packaging plant; the containers were then overwrapped with polyethylene. Kale in the other 1-bushel containers was washed, sorted, and repacked in new polyethylene-lined containers before it was snow iced. Both washed and unwashed kale from these containers remained almost unchanged during 1 week of storage at 32° or 40° F. The unwashed (field-packed) kale held up well at 32° for 4, 5, and possibly 6 weeks, with two-thirds to four-fifths remaining in marketable condition. After 2 weeks of storage at 40°, three-fourths of the unwashed kale was still marketable. But after 3 weeks at 40°, 100 percent of the unwashed and the washed kale was decayed or yellowed, or both.

The washed kale deteriorated more rapidly than the unwashed kale, but held up well at 32° F. for 2 and possibly for 3 weeks. At 40°, the washed kale held up well for only 1 week, although some was salvagable at 2 weeks. Beyond these time limits, decay was severe and little kale remained marketable. Yellowing was scarce during this test. However, in one examination after 3 weeks of storage at 40°, 66 percent of the kale was found to be yellowed.

Kale Experimentally Packaged as Consumer Units After Storage

Consumer Units Packaged From Field-Packed Containers of Kale

Even after bulk kale was stored in 1-bushel wood shipping and storage containers for 7 weeks at 32° F. or for 2 weeks at 40°, some high-quality kale was available for consumer packaging and shelf life tests. Before being placed at 70° for the shelf life tests (table 4), the kale experimentally packaged as consumer units in 10-ounce cellophane bags was rated "excellent" in appearance. Kale previously stored as long as 6 weeks at 32° or 1 week at 40° remained acceptable for 1 day at 70° after being packaged in consumer units. However, kale that had been stored for 7 weeks at 32° or 2 weeks at 40° before being packaged had less than 1 day of shelf life at 70°.

Consumer Units Packaged From Containers of Washed and Unwashed Kale

After the wirebound wood shipping containers of kale were removed from storage, the defective kale in each sample was discarded (table 3). The high quality washed and unwashed kale remaining was then experimentally packaged in 10-ounce Saran-coated cellophane bags (table 5). Immediately after being packaged, all of the kale was rated "excellent" in appearance and salable. Kale from some storage treatments was acceptable when packaged in bags, but had less than 1 day of shelf life at 70° F. Kale from other storage treatments had 1 or 2 days of shelf life at 70° after it was packaged.

Some washed kale was packagable when sorted from storage containers after 5 weeks at 32° F. or after 2 weeks at 40°. When packaged before storage or after 2 weeks of storage in wood containers at 32°, kale in 10-ounce bags was acceptable and fully salable for 1 day at 70°. However, washed kale that was packaged following 1 or 2 weeks of storage in wood containers at 40° was not aceptable after 1 day of holding at 70°.

Some unwashed kale from wood storage containers was packagable after 7 weeks at 32° or

TABLE 3.—*Spoilage* [1] *in washed, sorted kale and in unwashed field-packed kale, stored after icing* [2] *in wood containers lined or overwrapped with perforated polyethylene film* [3]

Storage temperature and treatment	Spoilage [4] found after storage for—						
	1 week	2 weeks	3 weeks	4 weeks	5 weeks	6 weeks	7 weeks
32° F.:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Washed	[4] 4. 5	12. 0	42. 6	59. 9	64. 6	76. 6	92. 6
Unwashed	3. 3	7. 4	10. 6	20. 8	28. 8	36. 7	72. 6
40° F.:							
Washed	4. 2	74. 1	100	----	----	----	----
Unwashed	5. 4	27. 4	[1] 100	----	----	----	----

[1] Spoilage consisted of decay only except for unwashed kale after 3 weeks at 40° F., where it consisted of 31.4-percent yellowing only, 34.6-percent yellowing with decay, and 34-percent decay only.

[2] Each 1-bushel container of kale received 1 shovelful of snow ice before being closed and stored.

[3] Polyethylene film for each container was perforated with 100 $\frac{5}{16}$-inch holes.

[4] Each value is based on 2 7.5 pound samples of kale from separate 1-bushel containers. Before storage, spoilage affected 2.1 percent of the washed kale and 7.4 percent of the unwashed kale.

after 2 weeks at 40° F. When packaged before storage, unwashed kale in 10-ounce bags was acceptable and fully salable after 2 days' holding at 70°. After storage in wood containers for 6 weeks at 32° or 1 week at 40°, unwashed kale in bags was acceptable after it was held for 1 day at 70°.

Commercially Packaged Consumer Units of Kale

Washed Kale Packaged as Consumer Units

When the 12-pack master cartons of kale (fig. 2) that had been washed, sorted, spin dried, packaged into consumer units, and packet iced by the commercial packaging plant arrived at the Beltsville laboratory, three cellophane bags of kale were removed at random for prestorage examination. The rest of the packages were selected at random, labeled, weighed, and placed in storage at temperatures of 32°, 40°, and 50° F. and 85- to 95-percent relative humidity. During storage, packages were removed from all three temperatures on the third, fifth, or seventh day, and other packages were removed weekly thereafter through the third week (50°), fourth week (40°), and seventh week (32°) (table 6).

After each examination before or after storage, the packaged kale was moved to a room maintained at 70° F. and 75-percent relative humidity and held for shelf-life tests. Kale in each package was reexamined after the first, second, or third day of holding for determination of weight loss, decay, and yellowing (table 6). Appearance and salability were also evaluated, but these data are not included in table 6. Tests were replicated three times. Data were processed by the analysis of variance and statistical differences between comparable averages were determined at the 1-percent level. For the analysis of variance, we used only the data for 3, 5, and 7 days of storage, with examination after removal, and after 1 and 2 days of holding at 70°.

Weight loss.—In general, weight loss from the consumer units of commercially washed and packaged kale increased with time in storage and time in the holding room at 70° F. following storage. During the first 3 weeks of storage, weight loss averaged about 0.25 percent per day at 32°. At 40°, weight loss was slightly larger, and it was twice as large at 50° than at 32°. Weight loss during holding at 70° was eight to 10 times as large as weight loss during storage at 32°. From data tested by the analysis of variance, we determined that significantly more weight was lost from kale from 50° storage (average 7.5 percent) than from 32° storage (average 5.2 percent). Weight lost

TABLE 4.—*Condition of unwashed field-packed kale initially stored in bulk in wood containers at 32° or 40° F., then sorted and packaged experimentally in bags [1] as consumer units and held for 1, 2, or 3 days at 70° [2]*

Temperature and time in storage for bulk kale	Defects and appearance [3] of kale packaged after storage and held at 70°											
	Weight loss after—			Decay [4] after—			Yellowing [4 5] after—			Appearance [6] after—		
	1 day	2 days	3 days	1 day	2 days	3 days	1 day	2 days	3 days	1 day	2 days	3 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Rating*	*Rating*	*Rating*
No storage	1. 5	3. 3	6. 4	0	4. 0	30. 0	1. 6	4. 0	48. 8	Excellent	Good	Poor.
32° F.:												
1 week	1. 9	4. 2	5. 4	0	5. 9	53. 2	2. 7	18. 7	79. 4	do	Fair	Do.
2 weeks	2. 1	5. 4	11. 0	0	7. 9	43. 7	1. 2	38. 7	79. 1	do	do	Do.
3 weeks	3. 3	6. 0	14. 7	0	9. 9	35. 3	11. 9	57. 9	87. 6	Very good	Poor	Do.
4 weeks	2. 4	4. 8	8. 1	0	14. 2	40. 1	9. 5	50. 6	81. 6	do	do	Very poor.
5 weeks	2. 5	4. 7	12. 3	0	15. 5	36. 1	10. 0	61. 9	91. 6	do	do	Do.
6 weeks	2. 0	5. 5	9. 4	0	30. 2	36. 1	12. 3	67. 9	94. 8	Good	do	Do.
7 weeks	3. 2	5. 0	--------	26. 4	42. 4	--------	27. 4	67. 7	--------	Poor	do	----------
40° F.:												
1 week	1. 6	3. 0	6. 9	0	57. 6	94. 5	1. 1	39. 6	86. 2	Excellent	do	Very poor.
2 weeks	3. 4	4. 6	10. 1	24. 8	44. 4	38. 5	35. 1	76. 8	100. 0	Poor	Very poor	Do.

[1] The bags were Saran-coated cellophane, each perforated with 8 ¼-inch holes.

[2] Relative humidity was 85 to 95 percent in the 32° and 40° F. storages, and 75 percent in the 70° holding room.

[3] Values are based on 5 consumer units of kale, each packaged from one of 5 crates for examination before storage, and on 2 to 5 units taken from 2 to 5 separate crates for each of the other examinations.

[4] Decay and yellowing data are not cumulative.

[5] Yellowing, as a defect, included only moderate, severe, and extremely severe yellowing (fig. 3).

[6] Packages of kale rated "excellent," "very good," and "good" were fully salable. Kale rated "fair" was barely salable. Kale rated "poor" and "very poor" was not salable.

TABLE 5.—*Condition of washed sorted kale and unwashed field-packed kale stored initially in bulk in wood containers at 32° or 40° F., then sorted and packaged experimentally in bags [1] as consumer units and held for 1, 2, or 3 days at 70° [2]*

Temperature and time in storage for bulk kale	Defects and appearance [3] of kale packaged after storage and held at 70°											
	Weight loss after—			Decay [4] after—			Yellowing [4 5] after—			Appearance [6] after—		
	1 day	2 days	3 days	1 day	2 days	3 days	1 day	2 days	3 days	1 day	2 days	3 days
Washed	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Rating*	*Rating*	*Rating*
No storage	3. 4	5. 8	12. 3	0	26. 2	70. 9	1. 3	1. 2	8. 4	Excellent	Poor	Very poor.
32° F.:												
1 week	3. 2	5. 8	11. 0	14. 8	44. 0	100. 0	3. 7	23. 2	81. 4	do	do	Do.
2 weeks	3. 6	8. 0	10. 4	0	64. 9	65. 3	4. 2	73. 3	84. 2	do	do	Poor.
3 weeks	3. 8	10. 0	15. 2	55. 6	92. 0	100. 0	14. 4	86. 8	56. 5	Poor	Very poor	Very poor.
4 weeks	3. 3	7. 1	9. 7	25. 4	41. 3	52. 5	1. 9	70. 3	94. 7	do	Poor	Do.
5 weeks	3. 8	9. 9		25. 0	59. 3		15. 2	73. 6		do	do	
6 weeks												
7 weeks												
40° F.:												
1 week	3. 9	6. 6	9. 4	33. 8	77. 9	100. 0	24. 4	70. 0	98. 5	Poor	Poor	Very poor.
2 weeks	7. 2			35. 2			74. 0			do		
Unwashed												
No storage	2. 4	4. 3	10. 4	0	0	57. 0	1. 5	1. 6	14. 0	Excellent	Very good	Poor.
32° F.:												
1 week	1. 9	4. 3	6. 5	0	8. 8	67. 6	2. 7	7. 4	74. 0	do	Good	Do.
2 weeks	3. 0	6. 0	9. 0	0	7. 6	63. 8	. 4	54. 2	74. 2	do	Fair	Do.
3 weeks	1. 9	3. 6	7. 2	0	1. 6	64. 4	6. 0	27. 6	79. 4	do	Poor	Do.
4 weeks	1. 8	3. 1	8. 2	0	14. 8	51. 2	2. 0	36. 2	75. 5	do	do	Do.
5 weeks	1. 5	3. 6		0	15. 2		1. 4	46. 5		Very good	do	
6 weeks	1. 6	2. 6	4. 2	0	60. 4	59. 0	14. 2	65. 0	86. 4	Good	do	Very poor.
7 weeks	3. 2	5. 0		26. 4	42. 4		27. 4	67. 7		Poor	do	
40° F.:												
1 week	1. 8	3. 0	6. 9	0	57. 6	94. 5	1. 1	39. 6	86. 2	Excellent	do	Very poor.
2 weeks	4. 2	5. 2		49. 6	88. 9		40. 6	80. 0		Poor	Very poor	

[1] The bags were Saran-coated cellophane, each perforated with 8 ¼-inch holes.

[2] Relative humidity was 85 to 95 percent in the 32° and 40° F. storages, and 75 percent in the 70° holding room.

[3] Each value is based on 2 consumer-unit bags of kale. Each bag was filled with kale from a separate container.

[4] Decay and yellowing data are not cumulative.

[5] Yellowing, as a defect, included only moderate, severe, and extremely severe yellowing (fig. 3).

[6] Packages of kale rated "excellent", "very good", and "good" were fully salable. Kale rated "fair" was barely salable. Kale rated "poor" and "very poor" was not salable.

TABLE 6.—*Condition of commercially washed and packaged consumer units*[1] *of kale stored at 32°, 40°, or 50° F.*[2] *in 12-pack master cartons, then held for 1, 2, or 3 days at 70° F.*[2]

Temperature and time in storage for kale in master cartons	Defects[3] of commercially packaged kale after storage and subsequent holding at 70°											
	Weight loss after—				Decay[4] after—				Yellowing[4 5] after—			
	No holding	1 day	2 days	3 days	No holding	1 day	2 days	3 days	No holding	1 day	2 days	3 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
No storage	0	2.3	3.5	5.3	0	1.3	11.9	16.2	0.7	1.3	8.6	53.3
32° F.:												
3 days	2.4	6.3	8.9	9.6	0	0	9.1	23.0	.4	5.1	33.1	63.7
5 days	2.8	4.7	5.9	9.7	0	0	22.3	------	.8	1.9	41.2	90.6
7 days	3.7	5.1	7.0	9.1	0	0	18.2	25.3	1.4	9.2	52.3	70.0
14 days	5.1	6.6	8.2	10.6	0	10.3	26.9	36.5	2.1	15.9	48.2	75.6
21 days	5.2	7.6	9.2	10.4	0	12.3	19.8	49.6	1.3	34.4	72.0	76.4
28 days	7.3	7.8	10.5	12.3	5.6	54.2	85.8	78.7	2.8	42.7	50.3	63.5
35 days	8.3	8.4	11.5	13.7	10.0	74.4	77.3	77.5	4.6	7.8	41.2	80.0
42 days	10.1	9.9	9.7	13.0	10.7	90.0	------	------	4.6	33.9	------	------
49 days	11.3	------	------	------	------	------	------	------	21.8	64.4	82.8	------
40° F.:												
3 days	2.4	5.5	10.4	9.2	0	0	12.1	------	2.2	11.6	42.0	65.1
5 days	4.4	6.1	8.9	------	0	11.2	16.1	------	1.6	20.6	71.2	------
7 days	3.1	5.0	7.6	9.4	0	13.6	21.9	------	10.0	37.2	73.1	81.4
14 days	4.5	8.0	10.2	15.4	2.4	30.5	30.8	------	17.5	67.1	78.4	83.2
21 days	6.0	9.5	11.9	------	26.5	29.1	63.1	------	52.2	86.5	84.8	------
28 days	7.0	9.1	------	------	26.8	42.2	------	------	82.0	82.0	------	------
50° F.:												
3 days	3.6	6.4	10.4	15.1	0	9.8	12.3	------	1.6	29.9	58.3	76.4
5 days	5.9	9.2	8.4	------	8.6	14.9	76.1	------	17.4	66.6	91.6	------
7 days	5.6	7.4	10.5	------	10.0	23.3	83.4	------	55.1	81.5	89.5	------
14 days	7.0	12.9	------	------	28.6	85.8	------	------	91.1	86.2	------	------
21 days	12.4	18.0	------	------	85.6	82.0	------	------	88.8	90.6	------	------

[1] Consumer units were 10-ounce Saran-coated cellophane bags, each perforated with 8 ¼-inch holes.

[2] Relative humidity was 85 to 95 percent in the 32°, 40° and 50° F. storages, and 75 percent in the 70° holding room.

[3] Each value is based on 3 10-ounce packages of kale.

[4] Decay and yellowing data are not cumulative.

[5] Yellowing as a defect included only moderate, severe, and extremely severe yellowing (fig. 3).

from kale from 40° storage was intermediate (average of 6.2 percent) and was not significantly different from the other two temperatures tested.

Decay.—No decay developed in packages of washed kale during 3 weeks of storage at 32° F., 1 week of storage at 40°, or 3 days of storage at 50°. Packages were also free of decay after 1 day of holding at 70° following previous storage for 3, 5, or 7 days at 32°, or for 3 days at 40°. However, kale in packages stored at 32° had 5.6-percent decayed leaves after 4 weeks of storage, and 10.7-percent decayed leaves after 6 weeks of storage. Decay also developed in over 10 percent of the kale in packages held for 1 day at 70° after previous storage for 2 weeks at 32°, and in 90 percent of the kale held for 1 day at 70° after previous storage for 6 weeks at 32°.

In packages held for 2 days at 70° F., decay occurred in 9.1 percent of the kale previously stored for 3 days at 32°, and in 77.3 percent of the kale previously stored for 5 weeks at 32°. The extent of decay at 70° was much greater for kale previously stored at 50° than for kale previously stored at 40° and 32°. From data tested by the analysis of variance, we determined that significantly more kale decayed after 50° storage (average 26.5 percent) than after either 32° or 40° storage (5.5 and 8.3 percent, respectively).

Yellowing.—The washed kale packaged by the commercial plant remained fresh and green and relatively free from yellowing after being stored for 4 to 6 weeks at 32° F., for 1 week at 40°, or for 3 days at 50°. Freshness was retained during 1 day of holding at 70° for kale in packages that had been previously stored for 1 week at 32° but not at 40° or 50° (fig. 5). Freshness was also re-

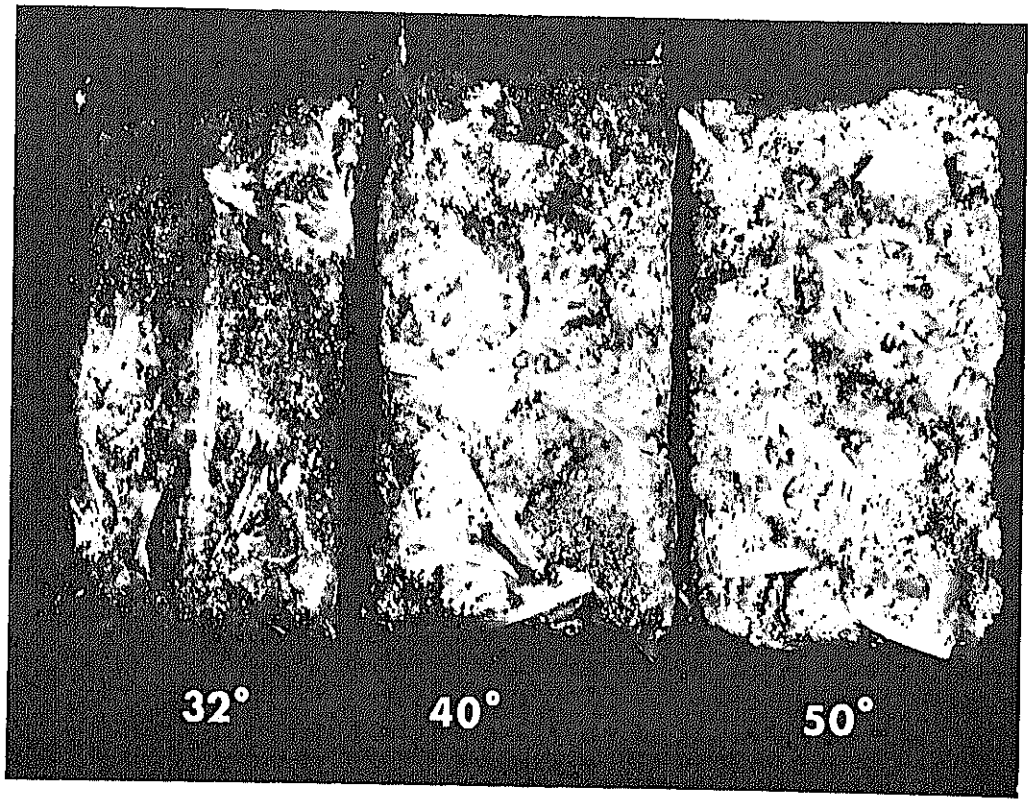

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FIGURE 5.—Commercially packaged washed kale held for 1 day at 70° F. after previous storage in corrugated master cartons (fig. 2). *Left to right*, After 1 day at 70°, kale previously stored for 1 week at 32° was fresh and green, but kale previously stored at 40° was moderately yellowed, and kale previously stored at 50° was severely yellowed.

tained in kale during 1 day of holding at 70° after storage for 3 days at 40°. However, when packages of kale were held for 1 day at 70° after previous storage for 2 weeks at 32°, for 5 days at 40°, or for 3 days at 50°, yellowing detracted from appearance and salability. From data tested by the analysis of variance at the 1-percent significance level, least kale (16.1 percent) yellowed during and after 32° storage, more kale (29.9 percent) yellowed during and after 40° storage, and most kale (54.6 percent) yellowed during and after 50° storage.

Appearance.—Packaged washed kale was rated "excellent" in appearance after 4 weeks of storage at 32° F., and after 1 day of holding at 70° following previous storage for 1 week at 32°. Packaged washed kale also rated "excellent" after 1 week of storage at 40° or 3 days at 50°. Packages of washed kale stored for 7 weeks at 32° or for 2 weeks at 40° retained acceptable appearance, and the appearance of packaged kale held for 1 day at 70° after previous storage for 2 weeks at 32° or for 3 days at 40° was also acceptable. Beyond these periods, however, kale deteriorated very rapidly at 40°, 50°, and 70°.

Salability.—Packaged, washed kale remained salable after 6 weeks of storage at 32° F., and after holding for 1 day at 70° after previous storage for 1 to 3 weeks at 32°. Kale stored in packages for 2 weeks at 40° also remained salable, as did kale held for 1 day at 70° after as much as 1 week of storage at 40°. Packaged washed kale that was stored at 50° for 3 days was salable, but after 1 day of holding at 70° following removal from 50° storage, the kale was found to be not salable.

Washed and Unwashed Kale Packaged as Consumer Units

As previously described, fresh washed and unwashed kale was packaged as consumer units in 10-ounce perforated cellophane bags by the cooperating commercial plant. The bags were then packed into 12-pack master cartons by the plant for storage and holding. At Beltsville, packages of kale were first removed at random for prestorage examination. The rest of the packages were selected at random, labeled, weighed, and placed in storage for 3, 5, or 7 days at 32°, 40°, and 50° F., and thereafter for up to 6 weeks at 32° or 3 weeks at 40°. At 50°, no packages were stored after the seventh day. Relative humidity in the 32°, 40°, and 50° rooms was maintained at 85 to 95 percent.

After the packages were removed from storage and examined, they were held for the shelf-life tests at 70° F. and 75-percent relative humidity. Packages were examined on removal from storage and after 1 and 2 days of holding for determination of weight loss, decay, and yellowing (table 7). Appearance and salability were also evaluated, but these data are not included in table 7.

The findings for longer storage of washed and unwashed kale continue the trend set by the data for kale stored for only 3, 5, and 7 days (table 7). Data for kale stored for 3, 5, and 7 days were processed by the analysis of variance at the 1-percent significance level. In this analysis, commercially packaged unwashed kale averaged significantly less weight loss (4.4 versus 6.2 percent), significantly less decay (8.7 versus 23.9 percent), but nonsignificantly more yellowing (36.8 versus 33.3 percent) than washed kale. Also, average percent weight loss, decay, and yellowing were each significantly lower in kale from lower storage temperatures than in kale from higher storage temperatures. Thus, in kale from 32°, 40°, and 50° F. storages, average weight loss was 4.4, 5.2, and 6.2 percent, respectively; average decay was 5.2, 15.4, and 29.8 percent, respectively; average yellowing was 17.6, 36, and 51.5 percent, respectively.

The unwashed packaged kale was often somewhat more attractive and remained salable longer than the washed packaged kale. For example, unwashed kale remained salable after 6 weeks of storage at 32° F., 2 weeks of storage at 40°, and 5 days of storage at 50°. Washed kale was salable for 3 weeks at 32°, 1 week at 40°, or 3 days at 50°.

The shelf life of the commercially packaged unwashed kale held at 70° F. was 2 days after 3 days of storage at 32°, and 1 day after 3 weeks of storage at 32°. The shelf life of the commercially packaged washed kale during holding at 70° was 1 day after 1 week of storage at 32° or after 3 days of storage at 40°.

TABLE 7.—*Condition of washed and unwashed kale commercially packaged in consumer units,*[1]

Temperature and time in storage for kale in master cartons[3]	Defects[3] of kale in consumer units after storage and subsequent holding at 70°					
	Weight loss after—					
	Washed kale			Unwashed kale		
	No holding	1 day	2 days	No holding	1 day	2 days
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
No storage	0	2. 9	4. 6	0	1. 5	2. 9
32° F.:						
3 days	3. 3	5. 3	6. 4	2. 1	3. 3	5. 0
5 days	2. 8	4. 7	5. 9	4. 8	3. 4	5. 2
7 days	4. 3	5. 4	8. 1	2. 2	2. 9	5. 0
14 days	6. 0	5. 8	7. 8	2. 9	4. 1	5. 9
21 days	5. 5	6. 4	8. 8	3. 2	4. 8	5. 2
28 days	7. 4	7. 8	10. 5	5. 6	6. 3	9. 1
35 days	7. 3	8. 4	11. 5	5. 2	6. 2	9. 0
42 days	9. 7	9. 9	9. 7	7. 3	8. 1	9. 3
40° F.:						
3 days	3. 3	4. 7	7. 3	3. 0	4. 9	5. 1
5 days	4. 4	6. 1	8. 9	2. 5	3. 7	6. 4
7 days	4. 7	6. 3	9. 9	3. 5	3. 6	6. 2
14 days	5. 9	9. 7	10. 8	3. 9	5. 5	6. 9
21 days	7. 1	9. 4	11. 9	5. 6	5. 8	8. 0
50° F.:						
3 days	4. 0	6. 1	9. 9	2. 9	4. 6	6. 3
5 days	3. 6	7. 0	8. 4	4. 0	4. 7	7. 2
7 days	7. 1	8. 8	10. 5	4. 0	4. 6	8. 2

[1] Consumer units were 10-ounce Saran-coated cellophane bags, each perforated with 8 ¼-inch holes.
[2] Relative humidity was 85 to 95 percent in 32°, 40°, and 50° F. rooms, and 75 percent in the 70° room.
[3] Each value is based on 1 10-ounce bag of kale.

stored in 12-pack master containers at 32°, 40°, or 50° F.,[2] then held for 1 or 2 days at 70° [2]

Defects [3] of kale in consumer units after storage and subsequent holding at 70°—Continued

Decay after [4]—						Yellowing after [4 5]—					
Washed kale			Unwashed kale			Washed kale			Unwashed kale		
No holding	1 day	2 days	No holding	1 day	2 days	No holding	1 day	2 days	No holding	1 day	2 days
Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	0	32. 8	0	0	0	1. 7	2. 6	17. 1	1. 1	1. 2	21. 7
0	0	23. 8	0	0	1. 2	. 3	1. 3	39. 7	0	. 9	33. 7
0	0	22. 3	0	0	2. 4	2. 5	1. 9	41. 2	1. 6	1. 7	52. 7
0	0	38. 5	0	0	5. 3	1. 6	16. 8	55. 3	. 3	4. 1	61. 3
0	30. 9	56. 4	0	1. 9	2. 8	3. 8	6. 1	43. 6	. 3	5. 0	57. 6
0	37. 0	33. 6	0	2. 7	4. 9	. 9	44. 0	76. 1	. 3	9. 4	58. 3
16. 8	54. 2	85. 8	0	0	39. 3	4. 4	42. 7	50. 3	1. 2	37. 5	60. 7
29. 9	74. 4	77. 3	0	21. 1	54. 8	4. 7	7. 8	41. 2	1. 2	16. 1	69. 3
32. 0	90. 0	--------	0	23. 1	--------	4. 6	33. 9	--------	2. 3	28. 4	--------
0	0	30. 5	0	7. 4	6. 9	. 9	2. 5	50. 0	. 6	15. 2	78. 6
0	33. 7	48. 2	1. 9	2. 6	9. 4	1. 6	20. 6	71. 2	2. 7	25. 9	76. 0
0	40. 7	69. 3	0	6. 9	20. 6	4. 7	54. 4	84. 7	16. 8	54. 8	87. 4
4. 6	80. 5	80. 3	0	4. 0	21. 0	20. 7	76. 6	83. 4	37. 2	79. 6	85. 3
79. 4	59. 6	63. 1	16. 5	43. 8	46. 8	57. 8	87. 2	84. 8	66. 0	90. 8	84. 3
0	20. 2	36. 7	0	13. 5	16. 9	. 6	4. 3	77. 0	1. 3	3. 4	84. 3
17. 0	38. 0	76. 1	0	17. 4	14. 3	11. 2	49. 7	91. 6	11. 5	57. 5	89. 3
23. 0	62. 9	83. 4	5. 3	42. 5	60. 5	38. 3	87. 2	89. 5	50. 1	88. 0	92. 8

[4] Decay and yellowing data are not cumulative.

[5] Yellowing, as a defect, includes only moderate, severe, and extremely severe yellowing (fig. 3).

SUMMARY AND CONCLUSIONS

Fresh kale wilts, respires, decays, and yellows rapidly under adverse handling, transportation, and storage conditions. However, its storage-life and shelf-life can be extended by proper handling and refrigeration.

For best quality maintenance, kale should be kept at 32° F. and high relative humidity (90 percent or above) throughout storage and marketing. It should also be refrigerated until it is either eaten raw in a salad or cooked and served as greens. Kale can be protected from spoilage by placing layers of crushed ice within the storage and shipping crates and by lining these containers with film, such as polyethylene. After storage, kale can be packaged in perforated moisture-retentive film bags and kept at 32°, with packets of crushed ice placed within the master cartons when necessary to supplement other refrigeration during wholesaling and retailing.

More careful harvesting and sorting of fresh kale before it is crated in the growing area could save 10 to 20 percent in shipping weight by eliminating weeds, trash, soil, and undesirable coarse or overmature kale.

At 70° F., whole kale leaves respire and produce heat at a rate of about 50,000 B.t.u.'s per ton every 24 hours—about 10 times the rate for kale held at 32°. Respiration rates for fresh kale leaves cut into strips are 20- to 25-percent higher than rates for whole kale leaves. The higher respiration rates in kale held at high temperatures and in kale damaged by cutting help to explain why such kale deteriorates faster than undamaged kale held at low temperatures.

In the tests conducted for this study, bulk kale protected by crushed ice and polyethylene-film crate overwraps or liners was maintained in excellent condition for 3 weeks at 32° F., 1 week at 40°, or 3 days at 50°. The crated bulk kale was still salable after 4 to 5 weeks of storage at 32°, after slightly less than 2 weeks at 40°, and for less than 5 days at 50°.

Kale removed from field-packed wood shipping containers before storage and experimentally packaged into 10-ounce perforated Saran-coated cellophane bags was held in good salable condition for 2 days at 70° F. However, kale experimentally packaged after previous storage in containers maintained at 32° or 40° remained in good salable condition for 1 day only when held at 70°. Kale that was sorted and experimentally packaged after 3 days of storage at 50° in bulk containers was acceptable when packaged, but was unsalable after 1 day of holding at 70°.

Kale packed into 10-ounce perforated Saran-coated cellophane bags soon after it arrived at the commercial packaging plant remained acceptable after experimental storage for 3 to 6 weeks at 32° F., for 1 to 2 weeks at 40°, and for 3 to 5 days at 50°. The commercially packaged kale was acceptable when it was held for 1 day at 70° after 1 to 3 weeks of storage at 32°, and after 3 to 7 days of storage at 40°. However, packaged kale stored for 3 days at 50° became unsalable after it was held for 1 day at 70°. This short shelf life should warn retailers and consumers that 70° is too high a holding temperature for packaged fresh kale. For best results, fresh kale should be maintained at a temperature near 32° until salad-making or cooking time.

Usually, kale is washed before it is displayed in bulk or packaged as consumer units in film bags. Consumers appreciate this service. Sorting and washing should also reduce subsequent spoilage. However, in these tests, washed kale remained acceptable for only half as long as dry-packed unwashed kale when both were stored at low temperatures and then exposed to a 70° F. holding temperature. Shorter storage and shelf life may be caused by mechanical damage to the kale during washing. Storage and shelf life may also be shortened by the spread of decay organisms from diseased to healthy kale by wash water. Careful handling, better sanitation, and more careful sorting to remove decayed leaves before kale enters wash water may reduce spoilage. Frequent changing or continuous flow of fresh wash water, rather than recirculation of used wash water, should reduce infection sources and help increase the storage and shelf life of fresh kale.

Storage life of fresh kale has been reported to be 10 to 14 days at 32° F. and 90- to 95-percent relative humidity (*9*). In the tests described in this report, kale in perforated film bags remained fresh and green after 3 to 6 weeks of storage at 32°, and after 1 day of holding at 70° following previous storage for 3 weeks at 32°.

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U.S. GOVERNMENT PRINTING OFFICE: 1970 O—420-852